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Initial water budget: the key to detaching large volumes of eclogitized oceanic crust in subduction zones?

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The Mesozoic, Neotethyan ophiolites and eclogites from the Zermatt-Saas area (ZS, Western Alps) represent a complete sequence of subducted lithosphere and the largest and deepest known piece of exhumed oceanic lithosphere so far (Bucher et al., 2005; Angiboust et al., 2009). Pervasive hydrothermal processes and seafloor alteration, which led to the incorporation of large amounts of fluid bound in the hydrated, upper layers of the oceanic crust, enabled the development of moderately (lawsonite eclogites) or strongly hydrated parageneses (glaucophanites, chloritoschists).

Although their exhumation may have been facilitated by the highly buoyant continental units underlying the ZS ophiolite (e.g., Monte Rosa) and/or the mechanically weak (and light) surrounding serpentinites, none of the other major ophiolite bodies from the same subduction zone (eg, Monviso, Voltri) show the same characteristics (ie, continuous mafic slices and abundant lawsonite). We therefore investigated the extent to which the hydration of the oceanic lithosphere may be a major parameter controlling exhumation, a process largely overlooked up to now.

Internally, the ZS ophiolite is made up of a series of tectonics slices of oceanic crust (150-300m thick) which are systematically separated by a 5 to 100-m thick serpentinite slivers. This stack of slices is separated from the underlying eclogitized continental crust (e.g., Monte Rosa) by a thick ($\sim$500m) serpentinite sole.

Field observations, textural relationships and pseudosection modelling reveal that lawsonite (now pseudomorphed by clinozoisite) was abundant and widespread in mafic eclogites when the ophiolite detached from the slab at c. 550°C and 24 kbar. Comparison between fresh eclogitic samples and thermodynamic modelling suggests that (i) water remained in excess from burial to eclogitic peak conditions, (ii) the lightest eclogitized metabasalts correspond to the portions of oceanic crust where metasomatism was most intense, (iii) crystallization of widespread hydrated parageneses (such as lawsonite, glaucophane and phengite), instead of garnet and omphacite, decreased rock density by 5 to 10 % and subsequently enhanced its flottability.

We propose that this density decrease acted as an efficient force to prevent these slices from irreversibly sinking into the mantle. Penetrative serpentinization of the slab mantle harzburgites during ridge-processes (Li et al., 2004) likely facilitated the detachment of theses slices from the downgoing slab and their stacking in the serpentinized subduction channel at pressures between 15-20 kbar. Exhumation of the underlying positively buoyant continental crust later dragged this “frozen” nappe-stack towards the surface.